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Abundance and distribution of Ixodid tick species infesting cattle reared under traditional farming systems in Tanzania

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Ticks and tick-borne diseases are serious constraints to livestock production in Tanzania and other sub-Saharan African countries. Despite this, knowledge on the abundance of tick species infesting cattle in most parts of Tanzania is insufficient or lacking. This study was conducted to identify species and establish the abundance of ticks infesting cattle in Mara, Singida and Mbeya regions of Tanzania. The ticks were collected from one side of the body, counted and identified, based on morphological characteristics; to species level. The mean tick count per animal was significantly higher in Mara (35.8±4.3, p=0.0001) as compared to Singida (12.9±2.1) and Mbeya (7.0±0.4) regions. Young animals in Mara (24.7±6.0, p=0.0395) and Mbeya (5.4±0.3, p=0.0252) exhibited relatively lower mean tick counts compared to the weaners (Mara = 33.8±6.5, Mbeya = 7.2±0.7) and adult animals (Mara = 46.3±8.4, Mbeya = 7.8±0.7). Seven tick species from three different genera, namely *Ambylomma*, *Hyalomma*, *Rhipicephalus* (including the subgenus *Boophilus*), were identified. However, only five species (*A. lepidum*, *A. variegatum, R. decoloratus, R. microplus* and *H. rufipes*) were observed in all the three regions. *R. appendiculatus* and *R. evertsi* were not found in Mbeya and Mara respectively. The most prevalent species in Mara, Singida and Mbeya were *R. appendiculatus* (50.5%), *A. lepidum* (31.2%) and *R. evertsi* (35.6%), respectively. This study showed the existence of a variety of tick species, most of them being of veterinary importance. Therefore, strategic planning and cost-effective tick control measures should be implemented in order to reduce losses caused by ticks and tick borne diseases in the study area.

Key words: Ixodid ticks, abundance, distribution, cattle, Tanzania

INTRODUCTION

Livestock keeping is one of the primary economic activities in Tanzania and contributes greatly to food security and income of small holder farmers. The livestock sector in 2014 contributed 4.4% to the National GDP of Tanzania (MLFD, 2014). Tanzania has 22.8 million cattle, 15.6 million goats, 35.5 million indigenous chickens, 24.5 million commercial chickens and 2.01 million pigs (MLFD, 2014) and 90% of agricultural households keep livestock of some kind. In importance, cattle come top followed by goats. In Tanzania 95% of the cattle population is reared under traditional agro-pastoral and pastoral husbandry systems (Msechu, 2001). Under such traditional rearing systems cattle are extensively grazed in pastures and forests and, hence, exposed to a high risk of tick infestation (Swai et al., 2005; Kwak et al., 2014; Laisser et al., 2014).

Ticks are the main vectors for disease causing agents (protozoa, bacteria, fungi and viruses) to humans, livestock and wild animals all over the world (Aydin et al., 2015). Ixodid ticks are harmful blood-sucking ectoparasites of cattle (Tsegaye et al., 2013) and are important vectors for tick-borne diseases (TBDs) such as East Coast fever, babesiosis, anaplasmosis and heartwater which affect cattle in Tanzania and other sub-Saharan African countries (Makala et al., 2003; Kivaria, 2006; Swai et al., 2007). The economic losses caused by the direct effects of these ticks include: Reduced cattle productivity, that is, milk yield, low quality of hides and skin and increased susceptibility to other diseases due to secondary infections (Tsegaye et al., 2013). About 80% of cattle populations in the world are at risk of tick infestation and TBDs (De Castro, 1997). It was already estimated at the end of the 20th century that the annual global cost associated with tick and TBDs in cattle ranges between 13.9 and 18.7 billion USD (De Castro, 1997). Ticks of the genus *Rhipicephalus* have been documented in Australia to cause reductions in cattle live-weight of between 600 and 900 g per animal during the entire period (three weeks) of feeding under conditions of low infestation and more than 2 kg during the same period under conditions of medium to high infestation (Sutherst et al., 1983; Johnson, 2006). In Africa, *R. appendiculatus* and *A. variegatum* have been reported to cause reductions of up to 4 and 46-61 g of live-weight gain per tick, respectively, during the entire period of feeding (Pegram et al., 2000).

A number of tick species are widely distributed all over the world, predominantly in tropical and subtropical countries (FAO, 1984). There are 840 well established species of ticks found worldwide parasitizing livestock, wild animals and human (Walker et al., 2003). In Turkey for example, more than 30 tick species have been identified (Dumanli et al., 2012). Of the 30 tick species identified, 15 of them namely *Rhipicephalus (Boophilus) annulatus, R. bursa, R. sanguineus, R. turanicus, Dermacentor marginatus, Hyalomma aegytium, H. anatolicum, H. detritum, H. Excavatum, H. marginatum, Haemaphysalis parva, Hae Puncatata, Hae Sulcata, Argas percicus* and *Ornithodorus lahorensis* have been observed in all parts of Turkey.

In East Africa more than 79 different tick species have been identified and documented, though most of these appear to be of little or no economic importance (Cumming, 1999). In Tanzania, Ixodid ticks of the genera *Rhipicephalus* and *Amblyomma* are the most important and widely distributed species found in many parts of the country where cattle are raised (Yeoman and Walker, 1967; Lynen et al., 2007; Kwak et al., 2014; Laisser et al., 2014).

Tick abundance varies with time, habitat and agro-ecological zones due to interaction of diverse factors such as host diversity and resistance, climate, absence of control measures and managerial activities that may affect the host behavior (Lightfoot and Norval, 1982; Punya and Hassan, 1992). Knowledge of tick abundance and species composition gives helpful information on tick population dynamics, disease transmission dynamics and estimates of resistance of different hosts (Norval et al., 1992). Thus, in order to establish effective control measures of tick borne diseases (TBDs), knowledge of tick abundance and species present in a particular area is very important as it helps in predicting the occurrence of definite TBDs in such an area. Studies aiming at quantifying tick species, tick control strategies and distribution among agro-pastoral and pastoral cattle populations in Mara, Singida and Mbeya regions are still limited. Existing information on ticks infesting cattle in Tanzania is somewhat obsolete (Yeoman and Walker, 1967; Kagaruki, 1991, 1996) and some is derived from studies based on knowledge and perception of livestock keepers on ticks available in their localities (Chenyambuga et al., 2010; Laisser et al., 2015). The published studies related to tick abundance and species composition was conducted in Ngorongoro (Swai et al., 2005), Iringa and Maswa (Kwak et al., 2014) districts of Tanzania. The most recent published information on tick abundance in Mara region was conducted by Laisser et al. (2014). However, their information is restricted to

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genus level.

The current study provides broad information on tickabundance and species infecting cattle in three regions of Tanzania (that is, Mara, Singida and Mbeya). Mara is situated in the lake zone between latitudes 1° 0' and 2° 31' south of the equator and longitudes 33° 10' and 35° 15' east of Greenwich and it is humid with annual mean rainfall of 1200 mm and altitude ranging from 1120 to 1300 m above sea level. Mbeya is located in the southern highlands between latitudes 7° and 9° south of the equator and between longitudes 32° and 35° East of Greenwich and has an annual mean rainfall of 1650 mm and an altitude of up to 2600 m above sea level. Singida is found in the semi-arid zone between longitudes 33° 27' 5" and 35° 20' east of Greenwich and latitudes 3° 52' and 7°34' south of the equator and is characterized by annual mean rainfall of 650 mm and altitude ranging from 1000 to 1500 m above sea level (MRSP, 1997; SRSP, 1997; MRUF, 2013). Furthermore, the results of the present study will highlight the various tick species present in the study areas. The presence of these ticks will also help to inform management decisions as to what are the probable tick-borne diseases that can be present in the study areas and many other areas that utilize pastoral and agro-pastoral cattle production systems and as such influence the design of effective control measures which can result into the improvement of the physical, economic and social wellbeing of livestock and livestock keepers in rural areas.

MATERIALS AND METHODS

Study area

This study was conducted in three regions of Tanzania, namely Mbeya, Mara and Singida. Mbeya is located in the western corner of the southern highlands of Tanzania and lies between latitudes 7° and 9° south of the equator and between longitudes 32° and 35° East of Greenwich (MRSP, 1997) (Figure 1). The region covers an area of 63,420 km^2 and is divided into eight administrative districts namely; Chunya, Ileje, Kyela, Mbarali, Mbeya, Mbozi, Momba and Rungwe. In this study, sampling was performed in Mbarali and Momba districts. Mean temperatures range between 16°C in the highlands and 25°C in the lowlands. Annual rainfall varies from 650 to 2600 mm and usually starts in October and goes through to May yearly (MRSP, 1997). The vegetation comprises of Miombo woodland dominated by *Broschystegion* and *Julbernardia* species, wooded grassland and bush lands of dense thickets of acacia and thorny trees. The region also supports evergreen forests and bamboo thickets. The region has 870,218 cattle, 544,473 goats, 98,222 sheep and 346,466 pigs and out of 870,218 cattle, 0.08 and 0.01% are improved dairy cattle and beef, respectively (NBS, 2012).

Mara region has a total surface area of 30,150 km^2 and lies between latitudes 1° 0' and 2° 31' south of the equator and longitudes 33° 10' and 35° 15' east of Greenwich (MRUF, 2013). Administratively the region is divided into six) districts, namely: Bunda, Butiama, Musoma, Rorya, Serengeti and Tarime. In this study sampling was undertaken in Tarime and Serengeti districts. The area is scaled with wide valleys, savannah vegetation and receives rainfall between 900 and1500 mm (MRUF, 2013) with mean temperatures ranging from 18 to 35°C. About 90% of residents in the region depend on agriculture as a main source oftheir livelihood. Livestock in Mara comprises 1,691,118 cattle, 913,524 goats, 418,077 sheep and 1741 pigs (NBS, 2012).

Singida region covers an area of 49,341 km^2 and is located in the central zone of Tanzania between longitudes 33° 27' 5" and 35° 20' east of Greenwich and latitudes 3° 52' and 7°34' south of the equator (SRSP, 1997). The region is divided into six (6) districts (Iramba, Ikungi, Manyoni, Mkalama, Singida district and Singida municipality). Sampling was carried out in Iramba and Mkalama districts. Most parts of the region are arid with annual rainfall ranging between 500 and 800 mm. The region has mean annual temperatures ranging between 15 and 30°C depending on season and altitude (SRSP, 1997). The vegetation is mainly dominated by *Acacia commiphora, Hyparrhenia* spp. grassland, *Brachystegia julbernadia* woodland and *Pseudoprosopis fischeri* bush thickets (Itigi thickets) (SRSP, 1997). The livestock population comprises 1,588,837 cattle, 839,169 goats, 477,772 sheep and 48935 pigs (NBS, 2012).

Research design

Sampling was carried out during the dry season, 2015 in the agro-pastoral and pastoral communities with the purpose of determining tick burden, species composition and their associated risk factors in cattle.

Study animals (local East African zebu) were divided into the following age groups, young (≤ 12 months), weaners (12 - 36 months) and adults (> 36 months). A total of 648 cattle (that is, 216 animals from each of the three regions), were investigated in this study. In each region two districts were purposively selected and four villages from each district were randomly selected, making a total of 24 villages from all the three regions. In each village, 9 households, 3 cattle from each household were randomly selected making a total of 27 animals per village. The required sample size (622) in all the three regions was determined as described by Chulaluk (2009) with an expected prevalence of 30, 96.4 confidence interval and an absolute error of 3.6%. However, in order to increase precision a total of 648 cattle were sampled.

Sampling procedure

Purposive sampling procedure was employed to select regions and districts. Selection of herds and villages was performed using a simple random technique after developing a list of all villages rearing indigenous cattle. Only households having at least ten cattle, including all age groups were included in this study.

Physical examination

The cattle were manually restrained by herdsmen to allow physical examination and sample collection. Each animal was subjected to physical examination such as evaluation of body condition score (BCS) and determination of animal age. Evaluation of BCS was based on 1 to 5 point scale as previously documented by Nicholson and Butterworth. (1986). We classified body condition scores into three groups as follows, BCS 1 and 2, BCS 3, BCS 4 and 5 for poor, average and good, respectively. Age of each animal was determined according to De-Lahunta and Habel. (1986). In addition, information on sex, frequency of tick control and tick control method used in each household was recorded.

Tick counting and collection

Tick burden on each animal was assessed by counting the number

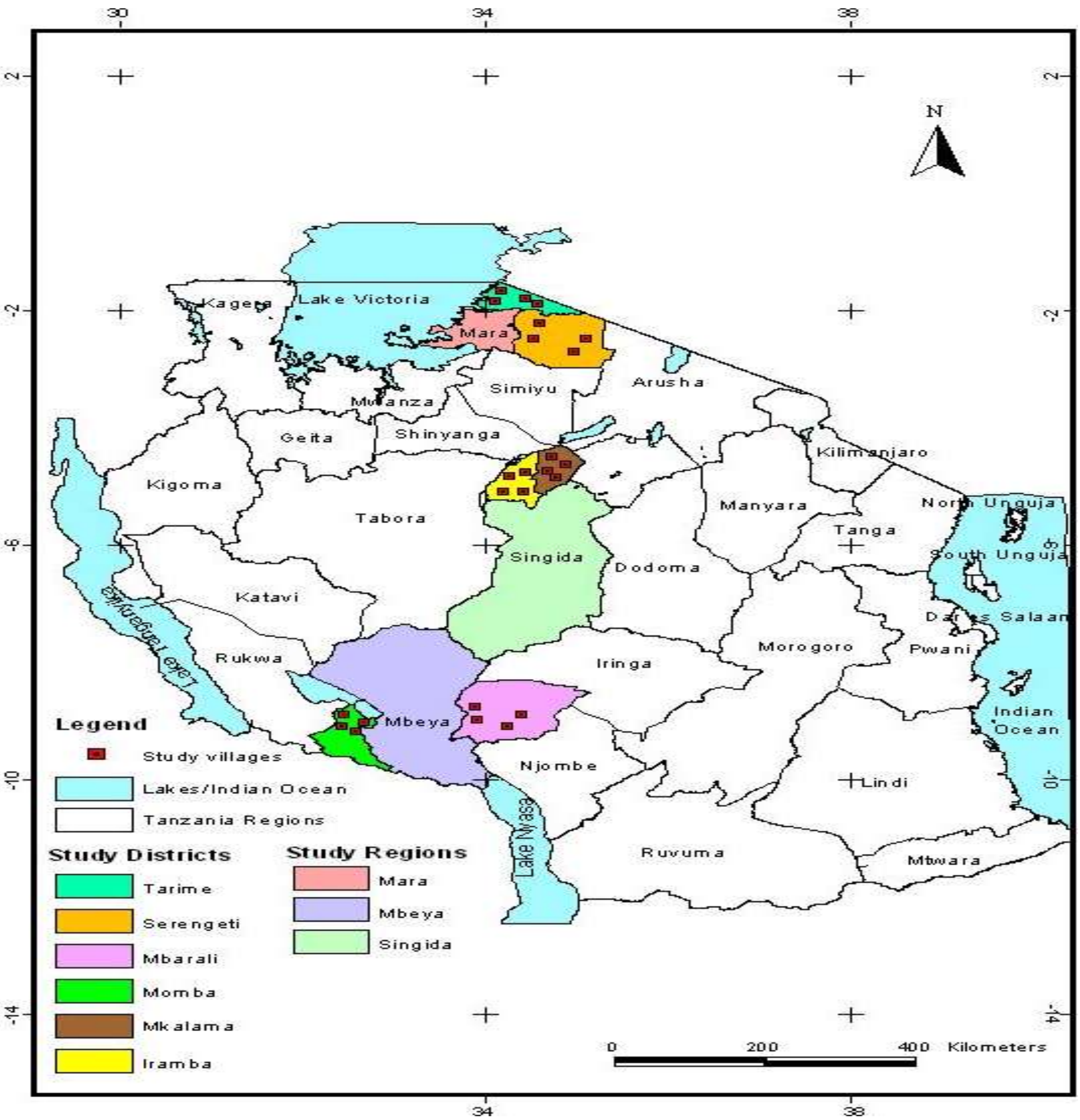

Figure 1. Map of the study area. Sampling was conducted in three regions (Mara, Singida and Mbeya). In each region two districts were purposively selected and four villages from each district were randomly selected, making a total of 24 villages from all the three regions.

of ticks (adult and nymph) from one side of the body and the result multiplied by two to represent the whole body of the animal. After counting, adult ticks were collected from each animal and stored in separate pre-labeled bottles containing 70% of ethanol. The ticks were identified based on morphological characteristics as described by Walker et al. (2003).

Data analysis

Data were initially entered into a Microsoft excel spread sheet before analysis. Graphical representation was also performed in Microsoft excel for windows (version 4.0). Mean tick counts and mean tick load for each species and their standard error (± SE) with 95% confidence interval (CI) were assed using General Linear Model (GLM) procedure of Statistical Analysis System (SAS) proprietary Software, Release 9.1 (SAS Institute Inc).

To determine the difference of means among categorical variables in each region, one way ANOVA was employed. Cumulative tick counts were statistically compared according to associated risk factors (age group, body condition score, sex, tick control method and frequency of tick control) in each region using Fisher's least significant different test. Values of $p \leq 0.05$ were considered significant.

RESULTS

Out of the 648 cattle examined, 392 (149, 114 and 129

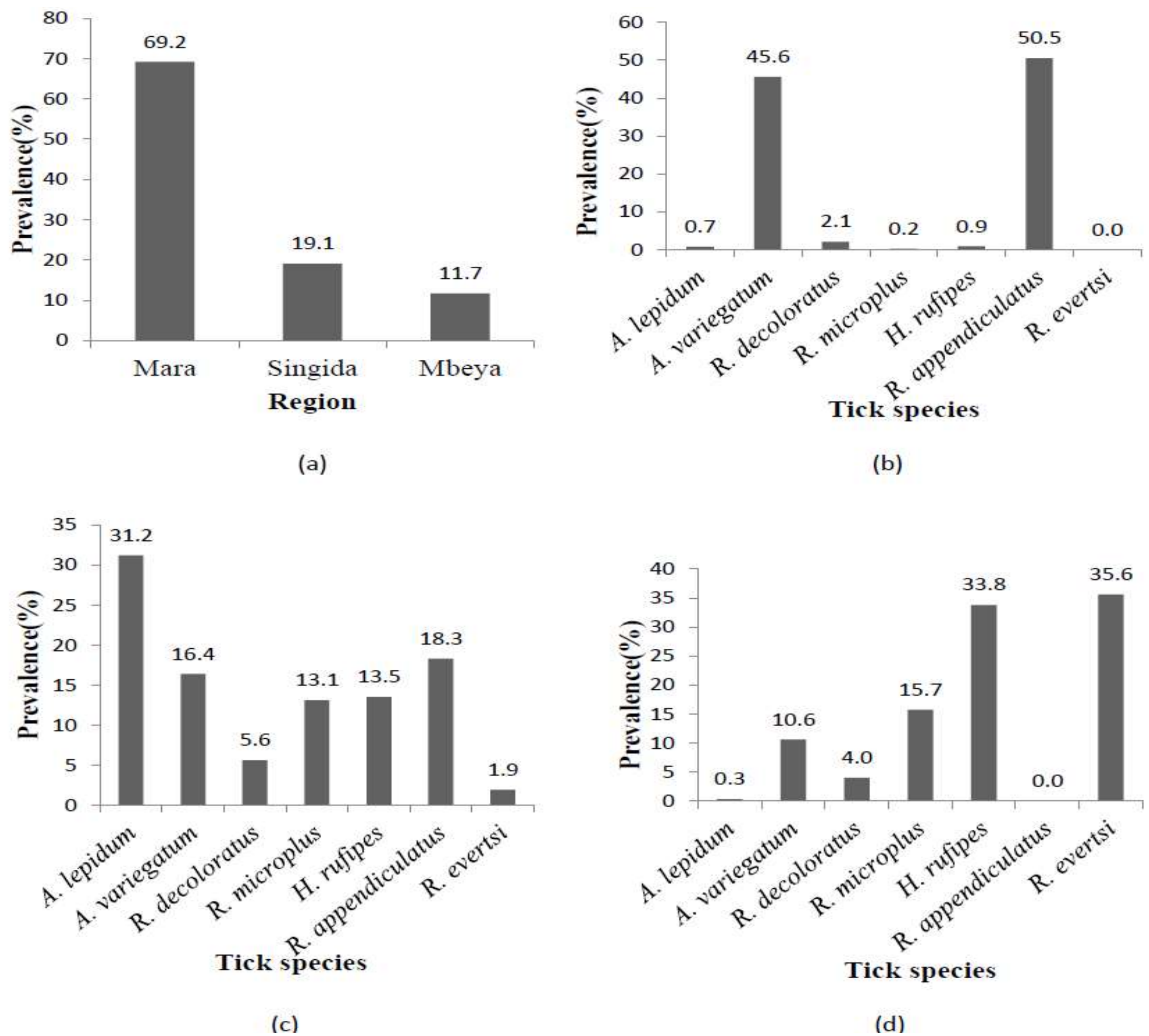

Figure 2. (a) Prevalence of total tick count by region (Mara, Singida and Mbeya), (b) prevalence of different tick species in Mara, (c) prevalence of different tick species in Singida, (d) prevalence of different tick species in Mbeya. The prevalence of ticks in Mara region (p=0.0001) was significantly higher than in Singaida and Mbeya regions. In Mara, *R. appendiculatus* (50.5%) was found to be the most abundant species followed by *A. variegatum* (45.6%). *Rhipicephalus microplus* (0.2%) was the least abundant species in this region. *Amblyomma lepidum* (31.2%) was the most prevalent tick species in Singida followed by *R. appendiculatus* (18.3%). *Rhipicephalus evertsi* (1.9%) was observed to be the least abundant species in the region. In Mbeya *R. evertsi* (35.6%) was the most abundant species followed by *H. rufipes* (33.8%). *Amblyomma lepidum* (0.3%) was the least abundant tick species observed in this region.

from Mara, Singida and Mbeya) were infested with ticks. A total of 7,705 ticks were observed in cattle from all the three regions. Of the 7,705 ticks, 69.2, 19.1 and 11.7%were observed in Mara, Singida and Mbeya regions respectively (Figure 2a). Mean tick count per animal was significantly higher in Mara region (35.3±4.3) and lower in Mbeya region (7.0±0.4) (Table 1). Three methods (dipping, hand spray and hand picking) of tick control were reported in the study area as depicted in Table 2. In Mara region all the three methods were practiced with dipping (54.2%) being the most common tick control method used in the region. Hand spraying

Table1. Number of infested cattle, Total number of ticks, and minimum, maximum and mean number of ticks per animal ± standard error (SE) across the regions based on General linear model

Risk Factor	Cattle	Tick count	Mean tick count/animal ± SE	Minimum	Maximum	p Value
Region						<0.0001
Mara	149	5331	35.8 ± 4.3^{a}	4	342	
Singida	114	1470	12.9 ± 2.1^{b}	4	216	
Mbeya	129	904	7.0 ± 0.4^{b}	4	24	

[a, b] values in the same column w ith the same superscript do not differ significantly (p ≤ 0.05) N= Number of cattle.

Table 2. Frequency and tick control methods practiced by households in each region based on descriptive statistics generated from frequency procedure of Statistical Analysis System (SAS).

	...…..Mara………			…….Singida…….			…….Mbeya…….			…….Overall…….		
Risk factor	**Household**	**%**	**P value**	**Household**	**%**	**P value**	**Household**	**%**	**P value**	**Household**	**%**	**P value**
Tick control method			< 0.0001			< 0.0001			< 0.0001			< 0.0001
Dipping	39	54.2		0	0		14	19.4		53	24.5	
Hand spray	20	27.8		62	86.1		22	30.6		104	48.1	
Hand picking	3	4.2		0	0		0	0		3	1.4	
No tick control	10	13.9		10	13.9		36	50		56	25.9	
Total	**72**	**100.0**		**72**	**100**		**72**	**100**		**216**	**100.0**	
Frequency of Tick control			< 0.0001			< 0.0001			< 0.0001			< 0.0001
Weekly	5	8.1		0	0		6	16.7		11	6.8	
Bi-Weekly	5	8.1		10	16.1		30	83.3		45	28.0	
Monthly	10	15.6		17	27.4		0	0		27	16.8	
Occasionally	42	68.2		36	56.5		0	0		78	48.4	
Total	**62**	**100**		**63**	**100**		**36**	**100**		161	**100**	

was the only method used to control ticks in Singida region and was practiced by 86.1% of the farmers whereas the remaining 13.9% did not use any tick control method. In Mbeya region hand spraying (30.6%) and dipping (19.4%) were the methods practiced by most farmers in controlling ticks, however 50% of farmers did not employ any tick control methods.

For tick control frequency, four practices were observed in the study area, namely weekly, bi-weekly, monthly and occasionally. In Mara region, the majority (68.2%) of the farmers controlled ticks occasionally, and these were followed by those (15.6%) who controlled ticks on a monthly basis. The remaining 16.2% either controlled ticks on a weekly basis or after every two weeks. In Singida, 56.6% of farmers controlled ticks occasionally whereas the remaining 16.1 and 27.4% controlled ticks bi-weekly and once per month, respectively. In Mbeya farmers were either controlling ticks on a weekly basis (16.7%) or after every two weeks (83.7%) (Table 2).

Mean tick counts per animal in relation to associated risk factors (age category, body condition score, sex, tick control method and frequency of tick control) for each region are presented in Table 3.

Significantly lower mean tick counts were observed in Mara and Mbeya region on younger animals than on other age groups. However, in Singida region no such statistical variation in mean tick count was observed among animals of different age groups. Cattle with poor body conditions exhibited higher mean tick counts than those with better body conditions in Mara and Singida regions. No significant difference was noted in mean tick numbers between animals with different body condition scores in Mbeya region. On the other hand, no significant difference was observed in mean tick counts between males and female cattle across all the three regions. Higher mean tick counts were observed in Mara (46.5±5.8) and Mbeya (9.7±1.4) in cattle managed under dipping system while hand sprayed animals had a low tick count. In Mara a lower mean tick count was observed on cattle which were under tick control practice done on a weekly and bi-weekly basis. In Mbeya where tick control was practiced on a weekly basis, animals exhibited a lower mean tick count than in those which were exposed to tick control every two weeks. However, no significant difference was observed on the mean tick count among cattle on different tick control frequency in Singida region.

When data from all the three regions were combined; young stock appeared to be associated with a lower mean tick count compared to other age groups, though statistically the differences were not significant (Table 3). Cattle with poor body condition score demonstrated higher mean tick count ($p = 0.0021$) than those with average and good body condition scores. Moreover, cattle exposed to frequent tick control measures (weekly and bi-weekly), were associated with lower mean tick counts ($p < 0.0001$) than those exposed to infrequent tick control practices (monthly and occasionally).

Furthermore, when all data were analyzed as a single population, dipping was associated with larger mean tick count per animal (41.6±5.1) than the other methods of tick control. On the other hand, hand spraying exhibited lower mean tick counts (10.4±1.5) compared to other tick control measures across the regions. Sex did not show any significant effect on the mean tick count per animal across the regions (Table 3).

A total of 3,784 adult ixodid ticks from 392 cattle were collected from three regions for identification purposes. Out of 3784 ticks, 2742 were males and 1042 were females with a Male: Female ratio of 2.6: 1. In Mara, Singida and Mbeya regions the total number of ticks collected were 1922, 1070 and 792, respectively. Three different genera (that is, *Ambylomma*, *Hyalomma* and *Rhipicephalus* (including the *Boophilus* subgenus) and seven tick species (*Amblyomma lepidum* (Dönitz, 1909), *Amblyomma variegatum* (Fabricius, 1794), *Rhipicephalus decoloratus* (Koch, 1844), *Rhipicephalus microplus* (Canestrini, 1888), *Hyalomma rufipes* Koch, 1844, *Rhipicephalus appendiculatus* (Neumann, 1901) and *Rhipicephalus evertsi* (Neumann, 1897) were identified. However, out of the seven tick species observed in the study area only five species (*A. lepidum*, *A. variegatum, R. decoloralus, R. microplus* and *H. rufipes*) were observed in all the three regions. Adults of the remaining two species, namely *R. appendiculatus* and *R. evertsi*, were restricted to Mara and Singida, and Mbeya and Singida regions, respectively (Table 4).

In Mara, *R. appendiculatus* (50.5%) was found to be the most abundant species (Figure 2b) with 12.1 ± 0.8 mean number of ticks per animal, followed by *A. variegatum* (45.6%) with a mean number of ticks per animal of 7.2 ± 0.4. *R. microplus* (0.2%) was the least abundant species in this region with the mean of 2.6 ± 1.1 ticks per animal. *A. lepidum* (31.2%) was the most prevalent tick species in Singida region (Figure 2c) with the mean of 6.0 ± 0.4 ticks per animal, followed by *R. appendiculatus* (18.3%) with 5.1 ± 1.2 ticks per animal. *R. evertsi* (1.9%) was observed to be the least abundant species in the region with the mean of 4.0 ± 0.8 ticks per animal. In Mbeya region *R. evertsi* (35.6%) was the most abundant species (Fig 2-d) with the mean tick number of 4.2 ± 0.2 per animal, followed by *H. rufipes* (33.8%) with the mean of 3.6 ± 0.3 ticks per animal. *A. lepidum* (0.3%) was the least abundant tick species observed in this region with the mean tick load of 2.0 ± 3.3 per cattle (Table 4).

When comparison was made across the regions, *A. lepidum* exhibited significantly higher mean tick count per animal in Singida region compared to the other regions. Mean tick numbers per animal for *A. variegatum* and *R. appendiculatus* were higher in Mara region than in the other regions. *H. rufipes* showed significantly higher number of ticks per animal in Singida region compared to other regions. However, the mean tick counts per animal for *R. decoloralus, R. microplus* and *R. evertsi* did not differ significantly across the three regions (Table 4). Sex ratio (Male: Female) was also recorded as shown in Table 4. *A. lepidum* exhibited the highest number of males compared to females in Mara (14: 0) and Singida (17.6: 1) regions. In Mbeya region only two females of A. lepidum were recorded. For *A. variegatum*, more males than females (3.3:1, 11.6:1 and 4.3:1 male: female ratio in Mara, Singida and Mbeya regions, respectively) were observed. With regard to *R. decoloratus* and *R. microplus*, larger numbers of females than males were observed in all the three regions. It was also observed that the number of males of *H. rufipes* was larger in comparison to that of females in all the three regions. For *R. appendiculatus* more males than females were observed in Mara and Singida regions. Only *R. evertsi* males were found in Singida and Mbeya regions.

DISCUSSION

In order to establish effective control measures of ticks and the diseases they transmit, knowledge of tick abundance and species present in a particular

Table 3. Amount of encountered ticks, Mean tick count/animal ± SE as influenced by associated risk factors in each region and across the regions.

Risk factor	…Mara region…			…Singida region…			…Mbeya region…			…Across the regions (Overall)…		
	N	Tick count	Mean tick count/animal ± SE	N	Tick count	Mean tick count/animal ± SE	N	Tick count	Mean tick count/animal ± SE	N	Tick count	Mean tick count/animal ± SE
Age category												
Young	44	1086	24.7±6.0[a]	21	172	8.2±1.7	31	168	5.4±0.3[a]	96	1426	14.9±2.9
Weaner	49	1654	33.8±6.5[ab]	38	628	16.6±6.0	46	330	7.2±0.7[b]	133	2612	19.6±3.1
Adult	56	2591	46.3±8.4[b]	55	670	12.2±1.2	52	406	7.8±0.7[b]	163	3667	22.5±3.2
p value			0.0395			0.3822			0.0252			0.2696
Body condition score												
Poor	112	4559	40.7±5.5[a]	56	908	16.2±4.2[a]	71	458	6.5±0.5	239	5925	24.8±2.9[a]
Average	37	772	20.9±3.7 [b]	55	538	9.8±1.0[b]	54	428	7.9±0.7	146	1738	11.9±1.1[b]
Good	0	0	0	3	24	8.0±2.3[b]	4	14	4.7±0.7	7	42	6.0±1.2[b]
p value			0.0438			0.0407			0.1517			0.0021
Sex												
Male	55	1690	30.7±7.8	50	700	14.0±4.3	55	348	6.3±0.4	160	2738	17.1±3.1
Female	94	3641	38.7±5.0	64	770	12.0±1.7	74	556	7.5±0.6	232	4967	21.4±2.3
p value			0.3662			0.6468			0.1575			0.2545
Tick control method												
Dipping	104	4835	46.5±5.8[a]	0	0	0	16	156	9.7±1.4[a]	120	4991	41.6±5.1[a]
Hand spray	24	152	6.3±1.0[b]	99	1280	12.9±2.4[a]	38	238	6.3±0.6[b]	161	1670	10.4±1.5[c]
Hand picking	4	62	15.5±10.8[c]	0	0	0	0	0	0	4	62	15.5±10.8[bc]
No tick control	17	282	16.6±2.9 [c]	15	192	12.7±2.8[a]	75	510	6.8±0.6[b]	107	982	19.2±0.8[b]
p value			0.0014			0.9668			0.0368			<0.0001
Tick control frequency												
Weekly	15	48	6.0±1.3[b]	0	0	0	18	32	4.0±0.0[b]	16	80	5±0.7[a]
Bi-Weekly	15	34	4.9±0.9[b]	30	92	7.7±1.1	90	362	7.9±0.7[a]	65	488	7.5±0.5[a]
Monthly	29	718	34.2±7.1[a]	51	332	11.4±1.5	0	0	0	50	1050	21.0±3.5[bc]
Occasionally	127	4249	44.3±6.2[a]	105	856	14.8±4.0	0	0	0	154	5105	33.2±4.3[b]
			0.0043			0.6024			0.0255			<0.0001

[a, b,c] values in the same column with the same superscript in each region do not differ significantly (p<0.05); N= Number of observed animals.

Table 4. Tick species count, mean tick load ±Standard error (SE) and Male (M) to Female (F) ratio by region based on General linear model

Tick species	Mara region: Total ticks	Mara region: Mean tick loads ±SE	Mara region: M	Mara region: F	Mara region: M:F	Singida region: Total ticks	Singida region: Mean tick loads ±SE	Singida region: M	Singida region: F	Singida region: M:F	Mbeya region: Total ticks	Mbeya region: Mean tick loads ±SE	Mbeya region: M	Mbeya region: F	Mbeya region: M:F	P value
Amblyomma lepidum	14	2.8 ± 0.5^{a}	14	0	14:00	334	6.0 ± 0.5^{b}	316	18	17.6:1	2	2.0 ± 0.0^{ab}	0	2	00:02	0.0428
Amblyomma variegatum	876	7.0 ± 0.5^{a}	674	202	3.3:1	176	4.5 ± 0.4^{b}	162	14	11.6:1	84	3.1 ± 0.3^{b}	68	16	4.3:1	<0.0001
Rhipicephalus decoloratus	40	2.9±0.3	0	40	00:40	60	4.6±0.9	0	60	0.6	32	3.6±0.6	10	22	0.6:1	0.1668
Rhipicephalus microplus	4	4.0±0.0	0	4	00:04	140	4.8±0.7	2	138	0.01:1	124	3.5±0.4	44	80	0.6:1	0.2501
Hyalomma rufipes	18	2.6 ± 0.4^{a}	14	4	3.5:1	144	5.5 ± 1.0^{b}	130	14	9.3:1	268	3.4 ± 0.2^{ac}	258	10	25.8:1	0.0038
Rhipicephalus appendiculatus	970	12.1 ± 1.0^{a}	576	394	1.5:1	196	5.0 ± 0.8^{b}	172	24	7.2:1	0	0	0	0	0	<0.0001
Rhipicephalus evertsi	0	0	0	0	0	20	4.0±1.3	20	0	20:00	282	4.2±0.2	282	0	282:00:00	0.8088

$^{a, b, c}$ values in the same column with the same superscript in each region do not differ significantly ($p<0.05$)

area is very important as it helps in predicting the occurrence of definite TBDs in such an area. The aim of this study was to assess the burden and species of ticks parasitizing cattle in three regions of Tanzania, namely Mara, Singida and Mbeya. Mara region is located in the north-west part of Tanzania while Singida and Mbeya are found in central and southern parts of the country, respectively.

In Mara and Mbeya regions, young cattle (≤ 12 months of age) exhibited a lower number of ticks than weaners and adults. The observed lower mean tick counts in young cattle compared to that of other age groups agree with the findings reported by Swai et al. (2005) in Ngorongoro, Tanzania. Similar findings have also been reported in Central Nigeria (Lorusso et al., 2013). Lower number of ticks on young animals compared to other age groups may signify that young animals are protected by innate age-related resistance which makes them less attractive to ticks than adult animals (Wickel and Bergman, 1997; Sutherst and Schnitzerling, 1982).

Furthermore, the possibility for ticks to attach on adult cattle than young stock when they are looking for a host is greater due to a larger surface area of the adult animals (Fivaz and Waal, 1993). Another reason can be attributed to progressive selective grooming of the calves' head, ears and neck from their respective dams (Fivaz and Waal, 1993). Additionally, in all the three regions investigated, young animals were grazed in areas close to the farmhouse while adult animals were grazed in grasslands and bushy areas located far away from the homestead as was the case in South Sudan (Kivaria et al., 2012), therefore reducing the risk of exposure of young stock to tick infestation. Adult animals continue to be at high risk of infestation with ticks due to prolonged mingling with other animals during grazing and watering since communal grazing lands are used. The observation in this study differs from the findings of Mwambene et al. (2012) who reported a different scenario in pastoral communities of southern part of Tanzania where all age groups grazed together and as a result all animals were subjected to an equal tick challenge.

From the three regions investigated, higher tick burdens on cattle were observed in Mara region compared to the others. This variability in tick burdens could be associated with geographical location (climate) and diverse tick control practices. Mara region ecologically favours growth and multiplication of ticks as it is more humid and receives more rainfall (MRUF, 2013). Despite the fact that more than 50% of livestock farmers reported that they dip their cattle for tick control, the prevalence of tick infestation was high because most of them dip their animals occassionally or when they observe severe tick infestation and this has accerelated the level of tick infestation on cattle in this region. On the other hand, Mbeya has an authoritarian community-managed dipping practice where it is mandatory for every famer to dip his/her animals at a designated frequency and this has significanly diminished the level of tick infestation in this region compared to Mara region where dipping is not compulsory. Hand spraying of cattle to control ticks was also practiced in all the three regions. In Mara and Mbeya, hand spraying significantly reduced the level of tick infestation in these two regions. A similar observation was reported by Simuunza et al. (2011) in Central, Eastern and Lusaka Provinces of Zambia whereby spraying was observed to be effective in the dry season.

In the current study, higher tick infestation was observed in animals with poor body condition scores in Mara and Singida and across the regions implying that cattle with medium and good body condition are less infested with ticks than those with poor body condition. Poor body condition in animals can be associated with poor management and nutritional status (Radostits, 2001). In particular, malnutrition can result into the lowering and deppression of the immune system and this, in turn, increases suceptibility of the animals to diseases and tick infestation, and failure to respond to vaccines and drugs (Radostits, 2001; Anderson et al., 2013). Our findings concur with other studies reported in Ethiopia (Tadesse et al., 2012; Onu and Sheferaw, 2013; Wogayehu et al., 2016). Futhermore, in the present study, sex had no significant effect on tick infestation among cattle studied, suggesting equal susceptibility of male and female animals to tick infestation. Similar findings have been reported in West Ethiopia (Amante et al., 2014) and South Western Ethiopia (Tadesse et al., 2012).

In the present study, only adult ticks were identified because immature ticks (larva and nymph) lack important morphological features required for identification to species level (Kaiser et al., 1982). The study observed a number of different tick species infesting cattle in the three regions. The three genera of ixodid cattle tick (that is, Ambylomma, Hyalomma and Rhipicephalus) identified in this study have also been reported by other researchers in some parts of Tanzania (Swai et al., 2005; Kwak et al., 2014; Laisser et al., 2014).

Similar findings have also been reported in Northwest Ethiopia (Moges et al., 2012), Adamawa and Northwest regions of Cameroon (Awaa et al., 2015) and central Nigeria (Lorusso et al., 2013). The presence of similar tick species in all the three regions in this study may be associated with unrestricted cattle movement from one area to another which is a common phenomenon in Tanzania. Of the tick species that were identified in this study, *R. appendiculatus* was the most abundant in Mara region, followed by *A. variegatum*. *R. appendiculatus* is a vector of *Theileria parva* which causes a fatal disease known as East Coast fever (ECF) in cattle (Mulumba et al., 2001; Konnai et al., 2006). East Coast fever has a considerable epidemiological and economic impact in the affected areas. In Tanzania the disease accounts for 68% of annual total losses due to TBDs in cattle (Kivaria, 2006). High abundance of *R. appendiculatus* in Mara region suggests the existence of ECF as previously reported by Laisser et al. (2014). Absence of *R appendiculatus* in Mbeya region has also been reported by Kwak et al. (2014) in Iringa region of Tanzania suggesting low risk of *T. parva* infection in the area.

Iringa and Mbeya regions are situated in the same agro ecological zone which is in the wet highland area with an annual mean rainfall of 1650 mm and an altitude of up to 2600 m above sea level (MRSP, 1997).

A. variegatum was the second abundant species in Mara region comprising 45.6% of the ticks observed. It was also observed across all the three regions. This species is the most common and widely distributed in Tanzania, covering sub-humid and low-to-high altitudes of the country (Lynen et al., 2007). The observations in our study are similar with the observations from a study by Swai et al. (2005) on tick management systems in Ngorongoro district of Tanzania. This species is of great veterinary importance because it is an efficient vector of *Ehrlichia ruminantium,* a causative agent of heartwater and stimulates the development of severe dermatophilosis, caused by *Dermatophilus congolensis* (Deem et al., 1996; Koney et al., 1996). Also *A. variegatum* has economic importance as it cause great damage to skin and hide due to its long mouth parts, lowering the value of the commodity on world market, especially when the number of ticks is large (Solomon et al., 2001). In addition, ulcers caused by this vector become complimentary location for secondary infection. *A. lepidum* was more abundant in Singida than Mara and Mbeya regions. Since *A. lepidum* needs more specialized environmental conditions, high abundance in this region could be attributed to its climatic condition which is semi-arid in nature with annual mean rainfall of 650 mm and an altitude ranging from 1000 to1500 m above sea level (SRSP, 1997). This species is an important vector of *Mycobacterium farcinogenes*, the causative agent of *Bovine farcy* (Hasabelrasoul et al., 2015), and it also transmits heart water.

Another important species found in the study area was *R. decoloratus* which was slightly more abundant in Singida region (5.6%) and Mbeya region (4.0%) and less abundant in Mara region (2.1%). Its relatively high abundance in these two regions compared to Mara region can be explained by its preference for highlands and sub-highlands receiving rainfall >800 mm annually (Pegram et al., 1981). This is in contrast to a study by Kwak et al. (2014) where *R. decoloratus* was not reported in Iringa region found in the southern highlands of Tanzania which is located in a similar agro-ecological zone as the Mbeya region.

According to Bekele (2002), relative abundance of *R. decoloratus* increases from lowland towards highland. Similar findings have been reported in Metekel Ranch of Ethiopia by Alekaw (1998).

R. microplus was also observed in all the three regions but the highest prevalence was noted in Mbeya region (15.7%). The higher prevalence of this species in Mbeya is of great interest because it is known to be a good vector of highly pathogenic *Babesia bovis* (Bock et al., 2004). In addition, this species in terms of control management is well-known to be resistant to numerous pyrethroid and organophosphate compounds (Baffi et al., 2008). Furthermore, *R. decoloratus* and *R. microplus* have great veterinary significance as they are important vectors of *Babesia bigemina* and *Babesia bovis,* which cause a disease called *bovine babesiosis* (De Waal, 2000; Jongejan and Uilenberg, 2004; Kocan et al., 2004). They are also vectors of *Anaplasma marginale* which causes anaplasmosis in cattle. These two tick species do not occur together due to interspecies competition despite their similar requirements for temperature and rainfall (Estrada-Peña et al., 2006).

H. rufipes is another tick species that was recorded in all the three regions, but with the highest prevalence in Mbeya (33.8%). This observation does not concur with Kwak et al. (2014) who assessed ixodid tick infestation in Iringa and Maswa districts of Tanzania. In their study this species was not observed.

According to Hoogstraal (1956) *H. rufipes* is largely distributed in most of the arid parts of tropical Africa which receives 250 to 650 mm annual rainfall. The findings of Hoogstraal (1956) are not in agreement with our observation in Mbeya region which has a wet highland climate, but exhibited a high prevalence of *H. rufipes*. It was expected that higher prevalence of this species would be observed in Singida region which is semi-arid in nature. The presence of this species in the three regions of Tanzania, regardless of differences in prevalence, is of great veterinary importance as it is known to transmit *A. marginale,* a causative agent of anaplasmosis in cattle (Potgieter, 1979). This species is also a good vector of *Theileria annulata* and *Babesia occultans* (Jongejan et al., 1983; Blouin and Van Rensburg, 1988).

Another species belonging to the *Rhipicephalus* genus observed in this study was *R. evertsi* which showed the highest prevalence in Mbeya region. This can be explained by its preference for wet highlands (Singh et al., 2000). This species has also been reported by Kwak et al. (2014) to be least prevalent in wild animals. Abebe et al. (2010) reported a 10.9% of *R. evertsi* in the Somali Regional State, Ethiopia. This species is also of veterinary importance since it transmits *B. bigemina* in cattle (Bock et al., 2004).

The present study did not find any *R. appendiculatus* in Mbeya region, and no *R. evertsi* in Mara region. According to Yeoman and Walker (1967), both *R. appendiculatus* and *R. evertsi* were present in both of the two regions. The results of the current study could probably be due to a real change in the tick populations since that time. In addition, there have been enormous changes since 1967 in the conditions required by the various tick species: Decrease of wild hosts, increase in the human population and domestic hosts, habitat changes in vegetation and climate, changes in agricultural activities including possibly an increase in tick control regimes and its effectiveness, which together may well have had a great influence on the tick populations.

For all the species that were collected for identification, males were found, as usually, to be predominant compared to females, with the exception of *R. decoloratus* and *R. microplus*. The male: female ratios observed in the present study correspond well with those reported by other studies (Tatchell and Easton, 1986; Lorusso et al., 2013; Bedasso et al., 2014).

The high proportion of males compared to females observed for *A. variegatum* is moreover associated with its biology. This species has a tendency to localize in preferential body areas such as udder, groin and scrotum and as a result forms emblematic clusters with few females attached with many males (Macleod, 1975; Ndhlovu et al., 2009). This is due to the aggregation-attachment pheromones (AAP) discharged by *A. variegatum* males and as such attracts unfed males, resulting into higher concentration of males than females on the feeding sites (Norval and Rechav, 1979).

Large number of males in relation to females for *H. rufipes* and *Rhipicephalus* spp*.* is most likely due to the fact that males have a tendency to remain on the host for a long time, continue feeding and mating with other females before dropping off (Solomon et al., 2001). The females of *Boophilus* ticks outnumbered males. The greater number of females noted for *Boophilus* ticks in this study agrees with the findings of other studies (Lorusso et al., 2013; Amante et al., 2014). This could probably be due to small size of males which may be overlooked during collection.

Conclusion

Ticks cause severe economic losses either by transmitting numerous diseases or by significant damage of hides and skin to the animals. The present study has shown that the prevalence of tick infestation was lower in Mbeya region where routine dipping on weekly basis has been adopted but higher in Mara region where dipping is occasionally practiced. The results show that young cattle which are grazed in the areas around homesteads have lower level of tick infestation compared to adult animals which are grazed in communal areas far away from the homesteads. The results further show that animals with poor body condition score exhibit higher level of tick infestation than those with good body condition score. Results from this study show that ticks of economic importance exist throughout the study areas, but the prevalence of each species differs from region to region. The predominant species during the dry season were *R. appendiculatus* and *A. variegatum* in Mara region, *A. lepidum* and *R. appendiculatus* in Singida region and *R. evertsi* and *H. rufipes* in Mbeya region. In order to reduce losses caused by ticks and tick borne diseases, appropriate and cost effective control strategies should be implemented. This should be done hand in hand with the Government to subsidize acaricides to farmers making them affordable. Since the present cross sectional survey was carried out only during the dry season, the authors recommend further study to be conducted in the study area during the rainy season.

ABBREVIATIONS

AAP, Aggregation-attachment pheromones; **ACP**, Africa Caribbean and Pacific; **ANOVA**, analysis of variance; **BCS**, Body condition score; **CI**, Confidence interval; **ECF**, East Coast fever; **EPINAV**, Enhancing Pro-poor Innovation in Natural Resources and Agricultural Value Chains; **FAO**, Food and Agriculture Organization; **GDP**, gross domestic product; **GLM**, General linear model; **MLFD**, Ministry of Livestock and Fisheries Development; **MRSP**, Mbeya Region Socio-Economic Profile; **NORAD**, Norwegian Agency for International Development; **SAS**, statistical analysis system; **SE**, standard error; **SUA**, Sokoine University of Agriculture; **TBDs**, tick borne diseases; **UNZA**, University of Zambia; **USD**, United States dollar; **MRUF**, Mara Region-The Unique Features; **SRSP**, Singida Region Socio-Economic Profile; **NBS**, National Bureau of Statistics.

Conflicts of Interests

The authors have not declared any conflict of interests.

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Ethics approval and consent to participate

The study was carried out with the full approval of households keeping cattle, district councils of the study areas, Sokoine University of Agriculture (SUA) and the University of Zambia (UNZA), School of Veterinary Medicine.

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